Basic Research for Nuclear Transmutation Techniques by Accelerator-Driven System (2) Deterministic Method (I): Analysis of the KUCA benchmarks with Deterministic Theory

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Abstract A set of ADS benchmark experiments performed in the KUCA-A core were analyzed with deterministic methods, most importantly few-group diffusion theory. Calculated values include the λ eigenvalue, prompt neutron decay constant α_p, as well as time-dependent calculations of pulsed operation. For nearly critical configurations satisfactory results were obtained for integral parameters; for deeply subcritical systems the results were poor, and specifically the determination of the reaction rate distribution on an indium wire gave very poor results.
Keywords: KUCA, ADS, deterministic theory, diffusion theory, transport theory, eigenvalues, prompt neutron decay constant, reaction rate distribution.

1. Introduction.In the KUCA A-core a series of experiments has been performed on an Accelerator Driven System (ADS) where neutrons are injected into a sub-critical core. Several of these experiments are available as benchmarks, one of which (see [1]) is analyzed in this work with deterministic methods. The KUCA core poses challenges for the analysis with deterministic methods. The classic two-step approach with diffusion theory is based on the assumption of an infinitely repeated lattice and a "large" reactor and mostly isotropic flux; these conditions do not apply to the KUCA ADS. However, calculations with deterministic theory are desired, for example for uncertainty analysis, kinetic parameters, etc, and therefore it is necessary to develop methods to model KUCA with deterministic theory (diffusion theory or transport theory).

2. Method Cross sections are generated with the ERANOS v2.0 code system (ECCO module). For this research a special 172-group cross section library was generated for ECCO. Core calculations are mainly done with the DALTON code. This code is based on diffusion theory and can calculate α-mode, λ-mode, fixed source, and time-dependent pulse mode. Core calculations for the λ-mode only are also done with the TGV-VARIANT module of ERANOS (nodal diffusion theory or transport theory). Since the KUCA-A benchmark consists of many core configurations and several types of experiment for each core configuration, a Python script was used to manage the automatic generation of all necessary input files.

3. Results The benchmark [1] has many results and it is impossible to discuss them all here. In **TABLE I** there is a selection of results. A detailed discussion of the results is presented in [2]. In general the measured data falls into two categories, (1) integral parameters: the λ eigenvalue and prompt neutron decay constant α_p, and (2) differential parameters, i.e. reaction rates on irradiation foils and/or indium wire. In the experiments the reactivity of the core is changed by removing materials from the core (reflector material, in some cases fuel is removed). Thus, the deeply subcritical cores have large voided areas and diffusion theory becomes invalid. As a result, the eigenvalues λ and α_p are calculated within 2% error for nearly critical critical configurations, but errors up to 15% appear for deeply subcritical configurations. In several experiments an indium wire was placed in the core to measure the thermal neutron flux. Unfortunately the calculated results are very poor in this case.

3-1. Modeling improvement for the indium wire measurements The analysis of the reaction rate on the indium wire was performed with a standard method used commonly in fast reactors: the flux is calculated without the presence of the indium wire; a flux traverse is then taken and comined with microscopic cross sections to obtain the reaction rate. Clearly this method fails for KUCA-A. Several improvements were investigated (optimized energy group structure, fine spatial mesh, treatment of self-shielding effect in the indium wire) but results were not improved. At present, an innovative approach based on reaction rate preservation is being investigated.

TABLE I: Example of results for integral parameters.

Case	Type	DALTON C/E	ERANOS C/E
I1	λ	0.997	1.001
I2	λ	0.997	1.001
I3	λ	0.996	1.000
I4	λ	0.996	1.001
I1	α_p	0.974	-
I2	α_p	0.899	-
I3	α_p	0.912	-
I4	α_p	0.865	-

4. Conclusion The KUCA-A benchmarks described in [1] were analyzed with deterministic methods. In general satisfactory results were obtained for the integral parameters k and α. However, the reaction rate on indium wire was not well calculated and a more detailed investigation is necessary. Simulations of pulsed operation with time-dependent diffusion theory gave good results.

References

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